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Special Report
97-S002

Water Quality Characteristics
in Navigation Pool 4
of the Mississippi River, 1990

December 1997

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Water Quality Characteristics in Navigation Pool 4 of the Mississippi River, 1990

by

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Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Environmental Management Technical Center, a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Program responsibility. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its multiple-use character. The long-term goals of the Program are to understand the system, determine resource trends and effects, develop management alternatives, manage information, and develop useful products.

This report was prepared under Task 2.2.3.6, *Evaluate and Summarize Current Monitoring Results* as specified in Goal 2, *Monitor and Evaluate the Condition of the Upper Mississippi River Ecosystem*, of the Operating Plan (USFWS 1993). This report was developed with funding provided by the Long Term Resource Monitoring Program.

Water Quality Characteristics in Navigation Pool 4 of the Mississippi River, 1990

by

Robert M. Burdis

Abstract

Resource Trend Analysis water quality monitoring was initiated in Navigation Pool 4 of the Upper Mississippi River in January 1990 as part of the Long Term Resource Monitoring Program. Water quality sampling was conducted in different habitats of the Upper Mississippi River System to interpret and predict short-term variability and long-term trends.

Introduction

Water quality plays a primary role in controlling the flora, fauna, and habitat found in the Upper Mississippi River System (UMRS). Many biotic and abiotic factors influence water quality, including land use practices, commercial and recreational navigation, municipal and industrial discharges, navigation control structures, and vegetation. An understanding of water quality trends and their mechanisms is rudimentary in developing a better understanding of the ecology of the UMRS.

Study Area

Navigation Pool 4 (Figure 1) of the Mississippi River is 71.1 km (44.2 miles) long, starting at Lock and Dam 3 about 8.8 km (5.5 miles) upriver of Red Wing, Minnesota, and ending at Lock and Dam 4 at Alma, Wisconsin. Pool 4 is unique to the Mississippi River in that it contains Lake Pepin, a natural riverine lake formed by the delta of the Chippewa River. Spanning almost half the distance of the pool, Lake Pepin is 33.4 km (20.8 miles) long, varies in width from about 1.6 to 3.2 km (1 to 2 miles), and has a surface area of 10,282 ha (25,408 acres) and a mean depth of 5.3 m (17.4 feet; Minnesota Pollution Control Agency 1989).

The mouths of three major tributaries empty into Pool 4. The Chippewa River, which has distinct water quality characteristics from those of the Mississippi, drains a 24,553 km^2 (9,480 square miles) area of Wisconsin and enters the Mississippi River just below Lake Pepin. The Cannon and Vermillion Rivers have drainage areas in Minnesota of 3,841 and 557 km^2 (1,483 and 215 square miles), respectively. Their confluence enters the Mississippi River about 1.1 km (0.7 mile) below Lock and Dam 3. Although not direct tributaries of Pool 4, the Minnesota and St. Croix Rivers influence water quality within Pool 4. The Minnesota River enters the Mississippi River 76 km (47 miles) above Lock and Dam 3, drains a 42,864-km^2 (16,550-square-mile) area in Minnesota, and carries a high suspended sediment load. The St. Croix River enters the Mississippi River from Wisconsin about 23 km (14 miles) above Lock and Dam 3 and has a drainage area of 20,098 km^2 (7,760 square miles).

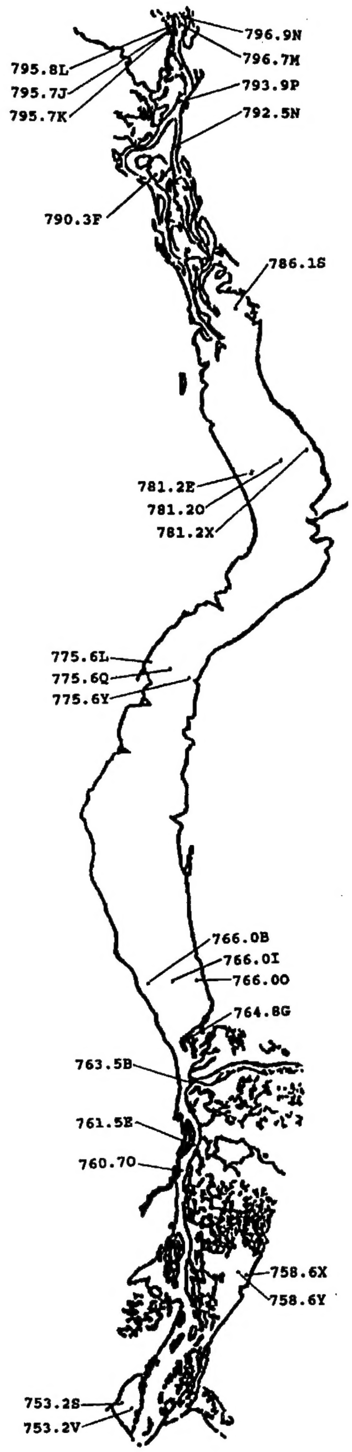

Figure 1. Location of Long Term Resource Monitoring Program water quality sites in Pool 4 of the Mississippi River.

Methods

Twenty-six water quality sites were established in selected habitats in Navigation Pool 4 of the Mississippi River (Table). Sites were chosen on the basis of winter accessibility and their representation of habitats found in the UMRS. Sites were selected along the length of the pool to determine if longitudinal changes in water quality occur within the same habitats. Where possible, both vegetated and nonvegetated sites were placed in backwaters to determine the effects of aquatic macrophyte beds on water quality. Three transects were monitored in Lake Pepin to determine both longitudinal and latitudinal differences within the lake. The mouths of three major tributaries were also monitored to determine their effects on water quality in Pool 4.

Water quality sites were sampled weekly except for two isolated backwaters that were sampled monthly. Water quality parameters were measured by techniques and equipment outlined in the Long Term Resource Monitoring Program (LTRMP) Procedures Manual (Lubinski and Rasmussen 1988). The following parameters were measured:

- Water temperature
- Specific conductance
- Current velocity and direction
- Water depth
- Wave height
- Ice and snow depth
- Dissolved oxygen
- Turbidity
- Secchi transparency
- Wind speed and direction
- Percentage of ice and snow cover

Report codes were used to indicate confidence in the accuracy of the data collected. A report code of 5 was assigned to data believed to be accurate and representative of a particular site. Report codes of 1 through 4 indicate disturbances or equipment malfunctions resulting in data that may not accurately represent a site. Only data with a report code of 5 were used in the present report.

Dissolved oxygen and temperature were measured with a Yellow Springs Instrument Model 57 dissolved oxygen meter (Yellow Springs Instrument Co., Inc., Yellow Springs, Ohio). Air calibration was made at the start and end of each sampling day; additional calibrations were made throughout the day when necessary. Precision and accuracy were checked monthly against Winkler's method for the determination of dissolved oxygen (DO). Because of the limitations of the Model 57, dissolved oxygen concentrations of >20.0 mg/L were arbitrarily given a value of 21.0 mg/L.

Secchi disk transparency was measured in centimeters with a disk mounted on a calibrated pole. A value of −9 was recorded when the disk could be seen to the bottom. Estimates of Secchi transparencies were later predicted from a regression of the natural log of turbidity on the natural log of Secchi transparency (Figures 2 and 3).

Current velocity was measured in meters per second with a Marsh-McBirney Model 201D velocity meter (Marsh-McBirney, Inc., Frederick, Maryland). An internal calibration check was performed at each site.

Turbidity was measured in nephelometric turbidity units (NTU) with a Hach Model 16800 PortaLab Turbidimeter (Hach Company, Loveland, Colorado). The meter was field-calibrated at each site to Gelex standards. Formazine calibrations were performed at least every 3 months, and precision and accuracy were checked monthly.

Specific conductance was measured in microsiemens (μS) at 25 °C with a LabComp Model SCT-100 conductivity meter (Cole-Palmer, Niles, Illinois). Calibrations were made at least weekly using a 1,000 μS/cm standard, and precision and accuracy were checked monthly.

Table. Long Term Resource Monitoring Program water quality sampling sites for Mississippi River Pool 4.

Location code	Location name	Habitat code[a]	Depth (m)	Sample frequency[b]	Vegetation code[c]
M796.9N	Tailwater	TWB	2.44	WK01	OP
M796.7M	Tailwater wing dam	TWW	2.19	WK01	OP
M795.8L	Isolated backwater	BWI-O	0.70	MT01	OP
M795.7K	Vermillion River	TRBM	2.74	WK01	OP
M795.7J	Cannon River	TRBM	1.75	WK01	OP
M793.9P	Channel border unstructured	CBU	1.93	WK01	OP
M792.5N	Wisconsin channel	SCU	1.05	WK01	OP
M790.3F	Mud Lake	BWC-O	1.09	WK01	OP
M786.1S	Bay City Flats	IMP-B	1.45	WK01	OP
M781.2X	L. Pepin - Wis. side	IMP-L	2.20	WK01	OP
M781.2O	L. Pepin - middle	IMP-L	5.35	WK01	OP
M781.2E	L. Pepin - Minn. side	IMP-L	7.13	WK01	OP
M775.6Y	L. Pepin - Wis. side	IMP-L	3.37	WK01	OP
M775.6Q	L. Pepin - middle	IMP-L	8.48	WK01	OP
M775.6L	L. Pepin - Minn. side	IMP-L	3.60	WK01	OP
M766.0O	L. Pepin - Wis. side	IMP-L	2.20	WK01	OP
M766.0I	L. Pepin - middle	IMP-L	5.83	WK01	OP
M766.0B	L. Pepin - Minn. side	IMP-L	11.41	WK01	OP
M764.8G	Isolated backwater	BWI-V	1.02	MT01	FL/SB
M763.5B	Chippewa River	TRBM	1.31	WK01	OP
M761.5E	Channel border unstructured	CBU	2.95	WK01	OP
M760.7O	Channel border wing dam	CBW	1.61	WK01	OP
M758.6X	Big Lake	BWC-V	1.13	WK01	FL/SB
M758.6Y	Big Lake	BWC-O	1.61	WK01	OP
M753.2V	Peterson Lake	IMP-V	1.16	WK01	SB
M753.2S	Peterson Lake	IMP-O	3.56	WK01	OP

[a] **TWB** = Tailwater channel border; **TWW** = Tailwater wing dam; **BWC-O** = Backwater contiguous—open water; **BWC-V** = Backwater contiguous—vegetated water; **BWI-O** = Backwater isolated—Open water; **BWI-V** = Backwater isolated—vegetated water; **CBU** = Main channel border unstructured; **CBW** = Main channel border wing dam; **IMP-B** = Impounded—bay; **IMP-L** = Impounded—lake characteristics; **IMP-O** = Impounded—open water; **IMP-V** = Impounded—vegetated water; **SCU** = Side channel unstructured border; **TRBM** = Tributary mouth.

[b] **WK01** = Weekly; **MT01** = Monthly.

[c] **OP** = Open water; **FL** = Floating-leaf rooted vegetation; **SB** = Submergent rooted vegetation.

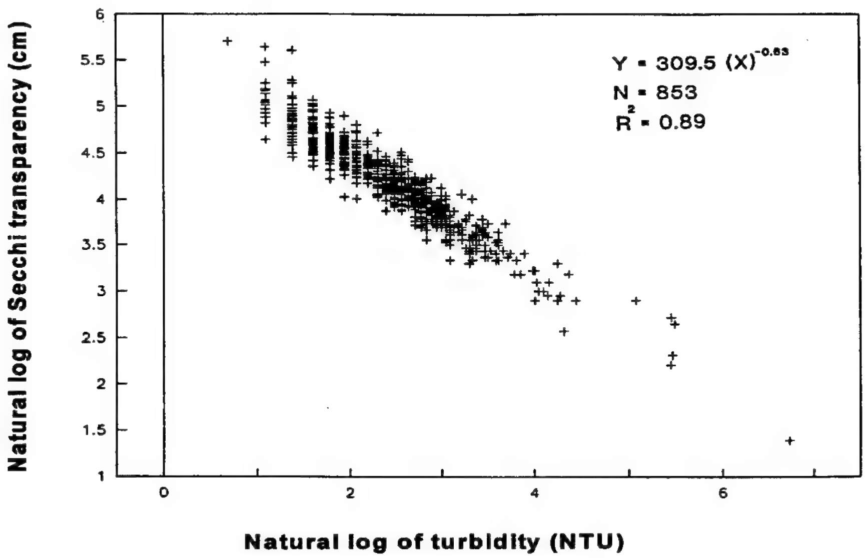

Figure 2. Regression of natural log of Secchi transparency on natural log of turbidity during open water.

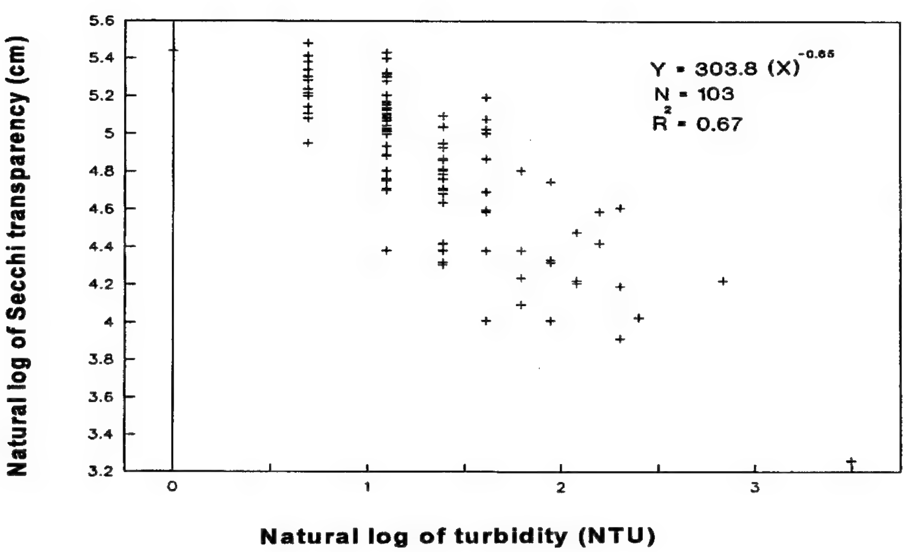

Figure 3. Regression of natural log of Secchi transparency on natural log of turbidity during ice cover.

Results and Discussion

For the sampling period of January through December 1990, temperatures were above normal from January through March and about normal for the rest of the year (Figure 4). Precipitation was above normal the first half of the year (particularly in June) and below normal later in the year (Figure 5). Discharge at Lock and Dams 3 and 4 (Figure 6) peaked during spring runoff and again in June because of heavy rainfall.

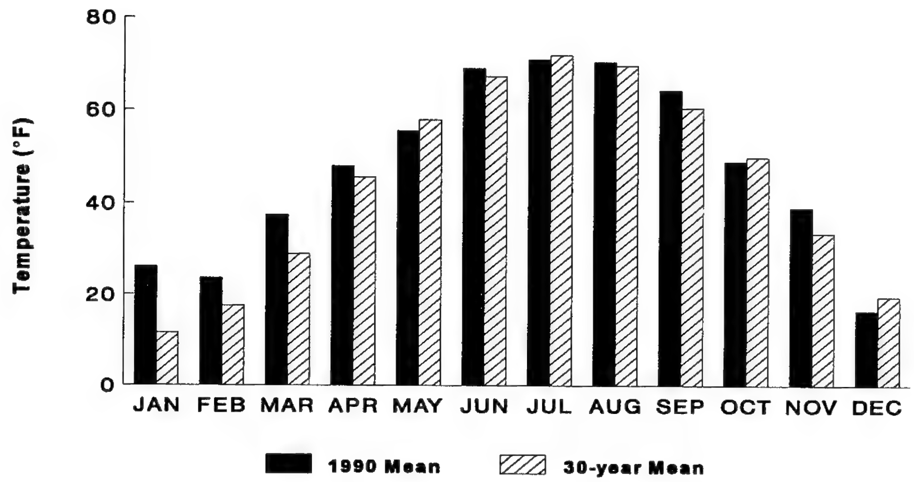

Figure 4. Comparison of 1990 and 30-year mean monthly ambient temperature for the Red Wing, Minnesota, area.

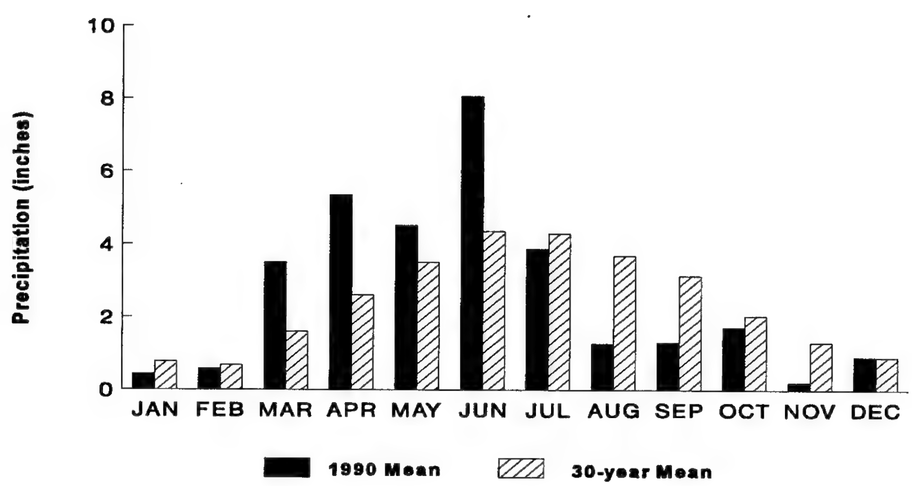

Figure 5. Comparison of 1990 and 30-year mean monthly precipitation for the Red Wing, Minnesota, area.

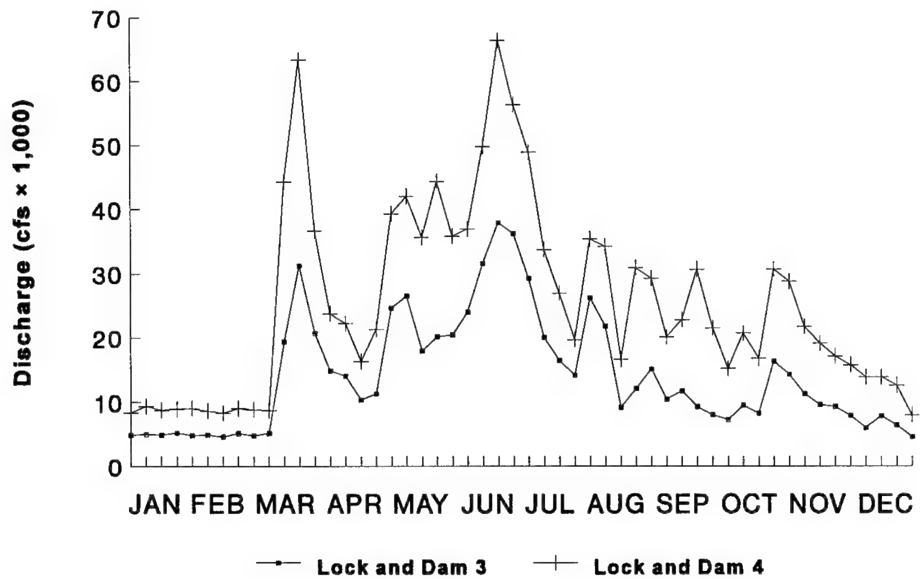

Figure 6. Mean weekly discharge (1990) at Lock and Dams 3 and 4.

Tributaries

The Vermillion River receives input from the Mississippi River through sloughs and from a number of backwater lakes before it empties into Pool 4. In its lower reaches, the Vermillion River has a low gradient and, consequently, relatively low current velocities (Figure 7) that allowed for some temperature and DO stratification. The supersaturated DO concentrations observed in the Vermillion River (Figure 8) were due to high densities of phytoplankton during low discharge. Surface water temperatures tended to be higher than in other tributaries (Figure 9), which can also be attributed to the lower gradient. Specific conductance (Figure 10) tended to be slightly higher than that of the main channel of the Mississippi River, indicating some differences in water quality. Turbidity and water clarity (Figures 11 and 12) did not seem greatly affected by heavy rainfall in the Vermillion watershed.

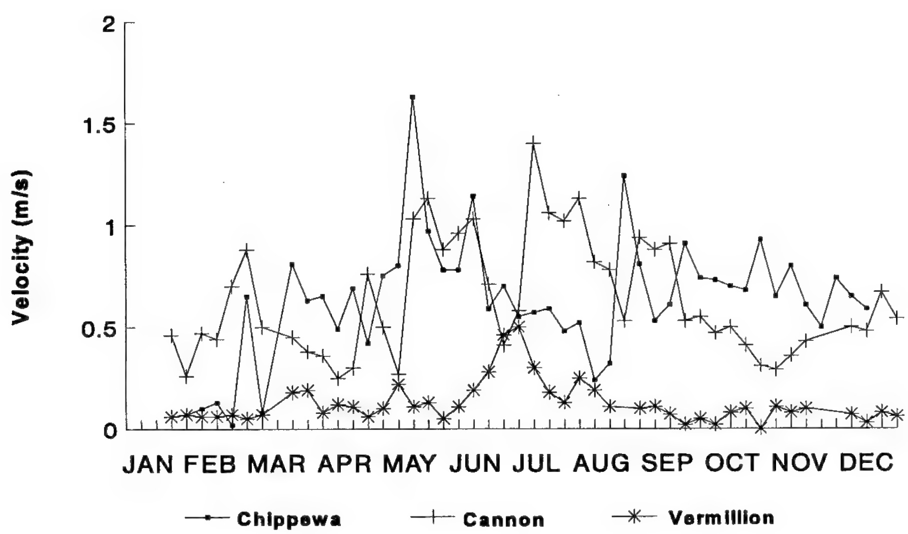

Figure 7. Surface current velocity at tributary mouths.

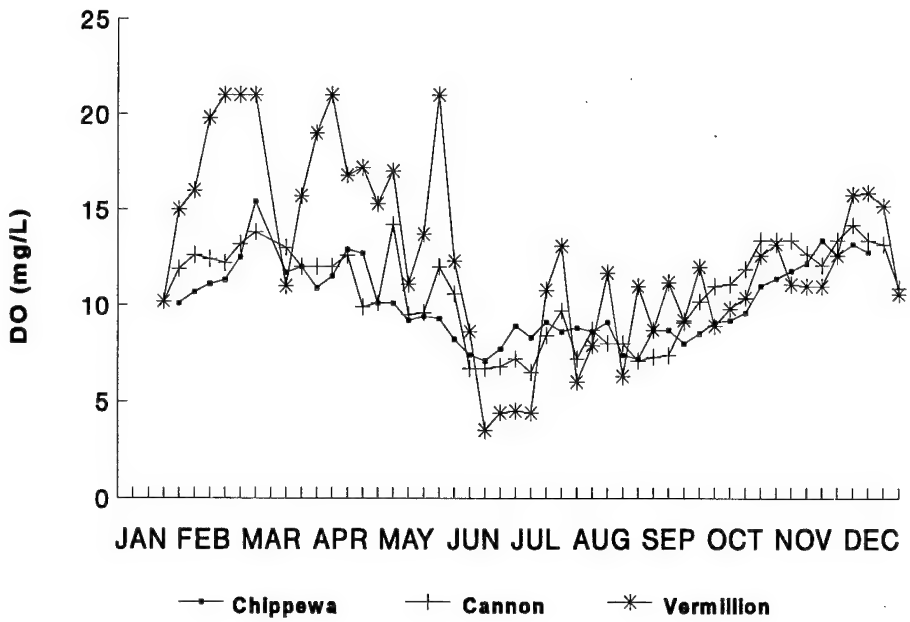

Figure 8. Surface dissolved oxygen (DO) at tributary mouths.

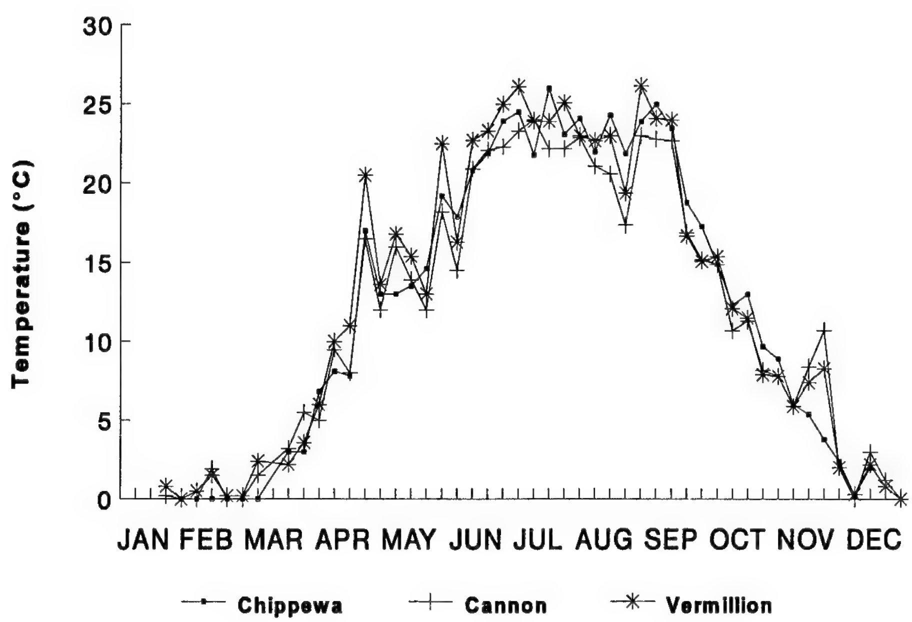

Figure 9. Surface water temperature at tributary mouths.

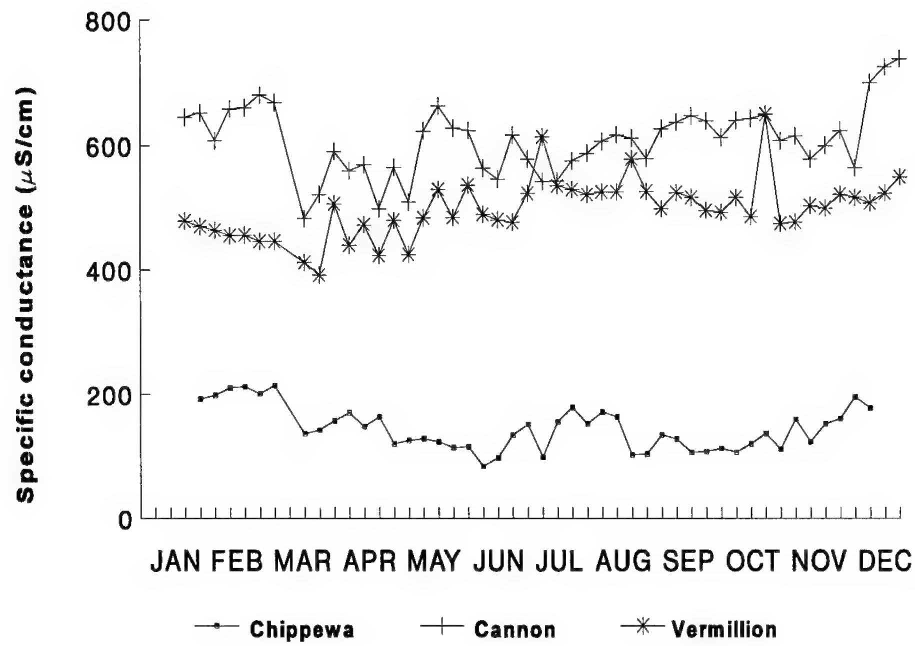

Figure 10. Surface specific conductance at tributary mouths.

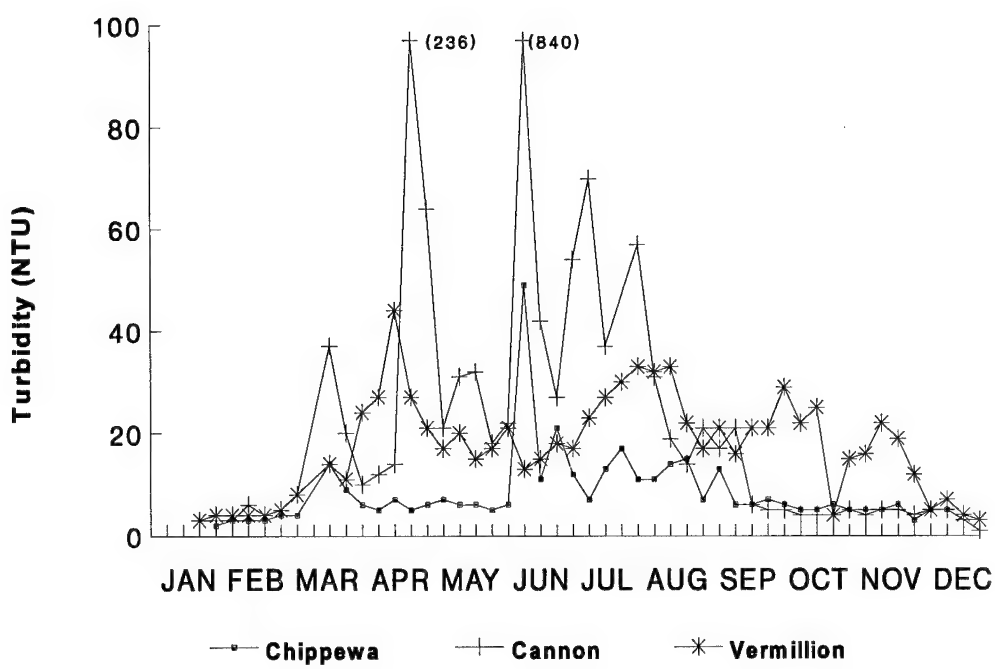

Figure 11. Surface nephelometric turbidity at tributary mouths.

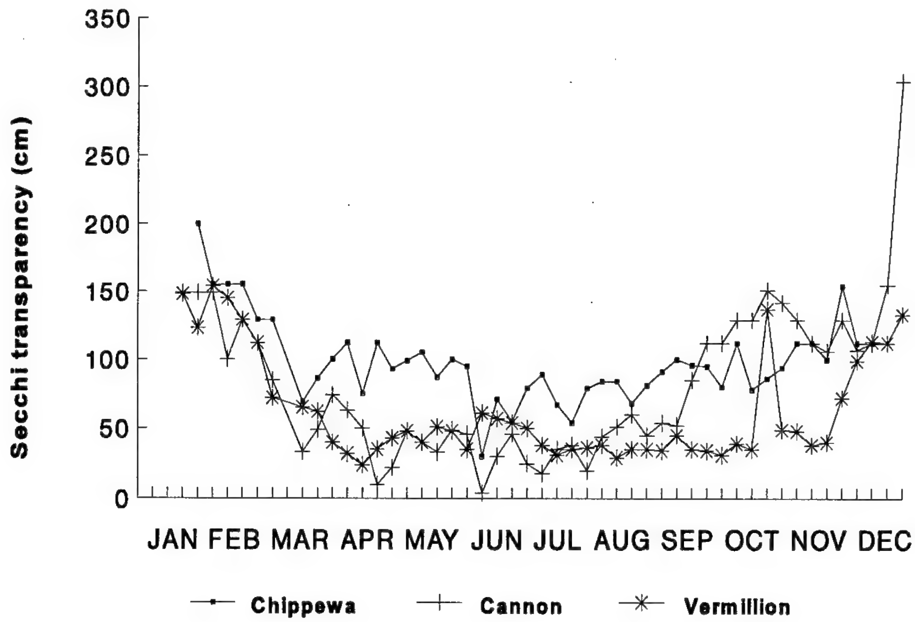

Figure 12. Secchi transparency at tributary mouths.

The Cannon River drains an area of steep slopes and highly erodible soils. This river is much more susceptible to episodic events than the Vermillion River, exhibiting much higher velocity and turbidity during periods of heavy rainfall (Figures 7 and 11). The Cannon River has a high concentration of dissolved salts and the highest specific conductance of all sites monitored (Figure 10). In summer, high numbers of blue-green algae (primarily *Aphanizomenon* sp.), which may have originated from upstream reservoirs, were at times observed at the mouth of the Cannon River.

The Chippewa River, the largest tributary of Pool 4, is characterized by low conductivity (Figure 10) and a high concentration of dissolved organic matter. Although the river transports a large bed load of sand, it does not typically carry a high concentration of suspended solids; hence, turbidity levels are relatively low (Figure 11). The blue-green algae *Microcystis* sp. was present in high numbers in summer. During high flows in the Chippewa River, large areas of lower Pool 4 (particularly Big Lake, a contiguous backwater) are influenced by this tributary.

Lake Pepin

As the Mississippi River enters Lake Pepin in the middle of Pool 4, the current slows, allowing Lake Pepin to act as a giant settling basin for suspended material. This settling effect greatly reduces turbidity and increases water clarity in a downstream direction (Figure 13), resulting in a wide range of turbidity and Secchi transparency values from upstream to downstream (Figures 14 and 15). Wind and wave action along the relatively shallow basin, with a maximum fetch of 19 km (11.8 miles), often cause resuspension of sediments and increased turbidity levels, particularly in the lake's upper end and in shallow bays such as Bay City Flats. Sediments in most areas of Lake Pepin are typically silt, and turbidity levels near the bottom are often higher than those at the surface.

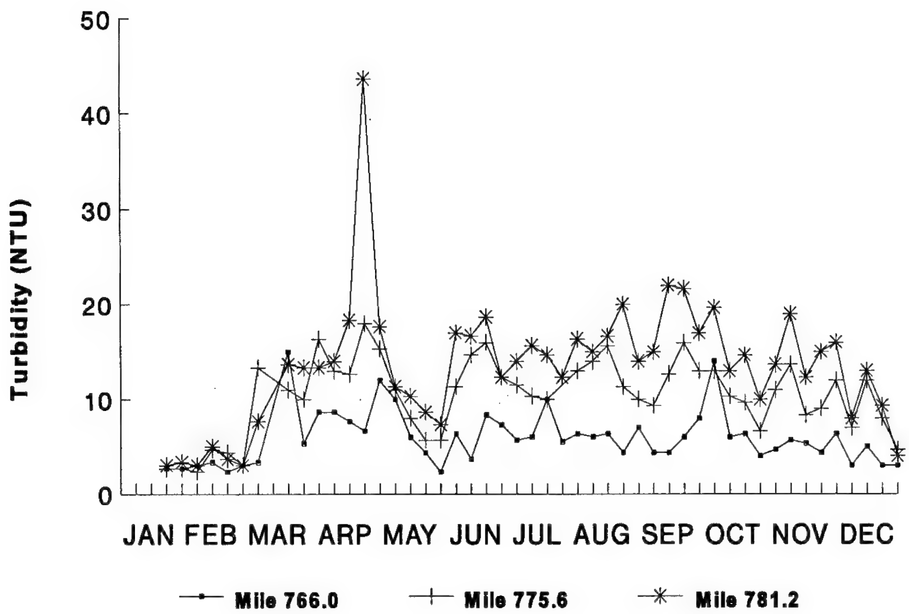

Figure 13. Mean surface nephelometric turbidity along three transects in Lake Pepin.

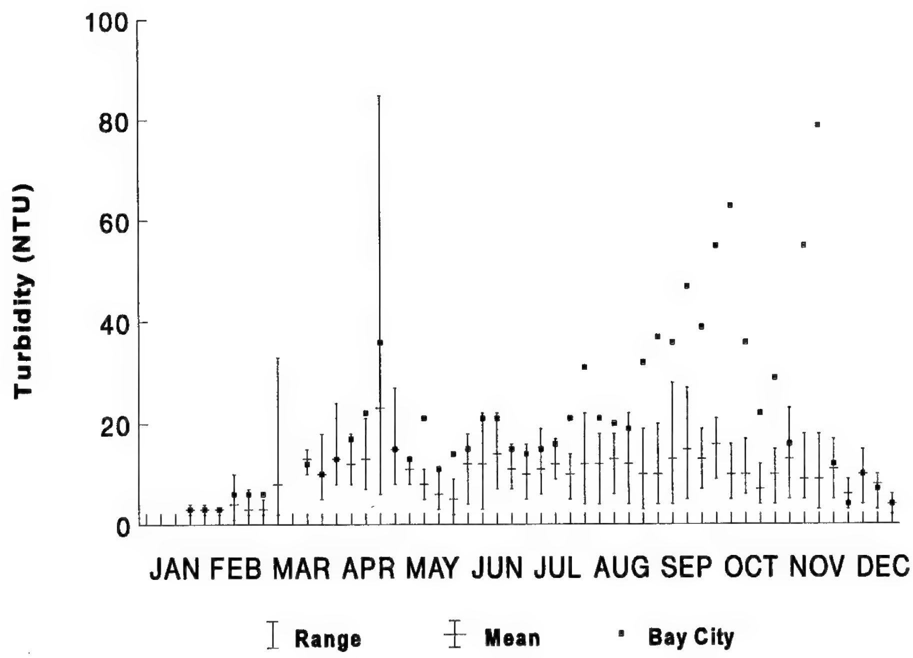

Figure 14. Mean and range of surface nephelometric turbidity in Lake Pepin (Bay City is treated separately).

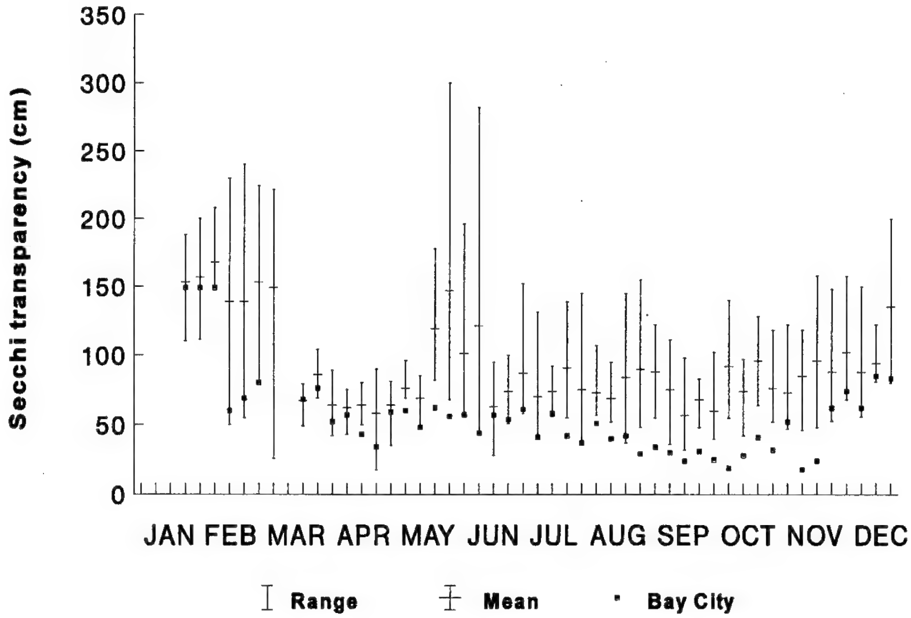

Figure 15. Mean and range of Secchi transparency in Lake Pepin (Bay City is treated separately).

Dissolved oxygen stratification occurred in Lake Pepin during winter and occasionally during summer. Although complete turnover of the water column occurred only in spring and fall, Lake Pepin fluctuated in summer between stratified and well mixed depending on wind conditions. This process is shown in dissolved oxygen isopleths for the middle sites along three transects in Lake Pepin (Figures 16–18). Stratification occurred less often and to a lesser degree at sites with higher flows along the Minnesota shoreline. During stratification, when winds blew from one shore to another, warmer, well-oxygenated water from the surface accumulated on the windward shore while cooler, less-oxygenated water from the hypolimnion predominated on the leeward shore, resulting in a wide range of surface DO concentrations and temperatures in the lake (Figures 19 and 20). During winter and summer stratification, supersaturated levels of DO occurred in the epilimnion because of high algae production. The DO levels in the hypolimnion quickly dropped below 5.0 mg/L during summer stratification (Figures 16–18).

A decrease in specific conductance in Lake Pepin and in other Pool 4 habitats in March and April (Figure 21) can be attributed to the dilution effect of spring runoff. Conductivity also decreased in fall, but its causes are uncertain.

Lake Pepin is a eutrophic lake known for its occasionally large algal blooms. The blue-green algae *Aphanizomenon* sp. and *Microcystis* sp. were observed throughout summer. High densities of the zooplankton *Daphnia* sp. were also observed in the lower end of Lake Pepin in early June.

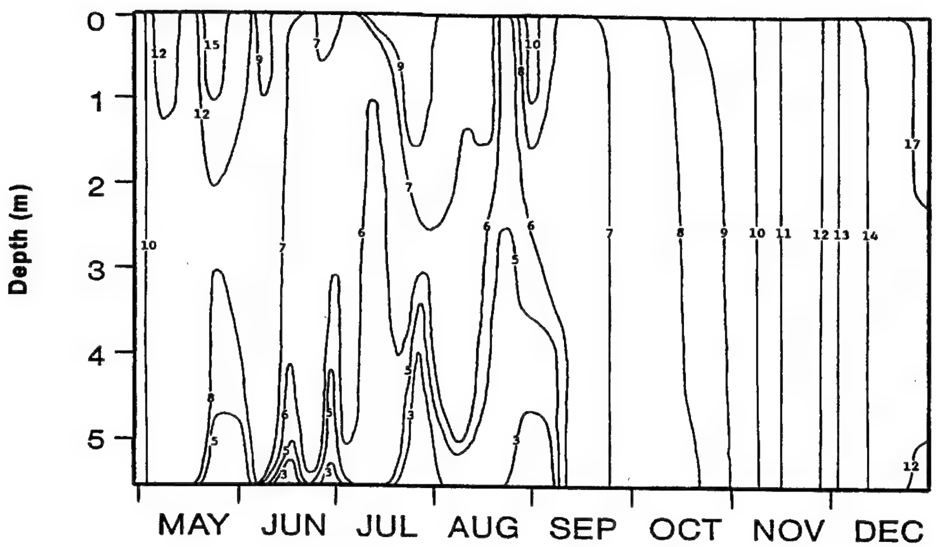

Figure 16. Dissolved oxygen isopleths for upper Lake Pepin site M781.2O.

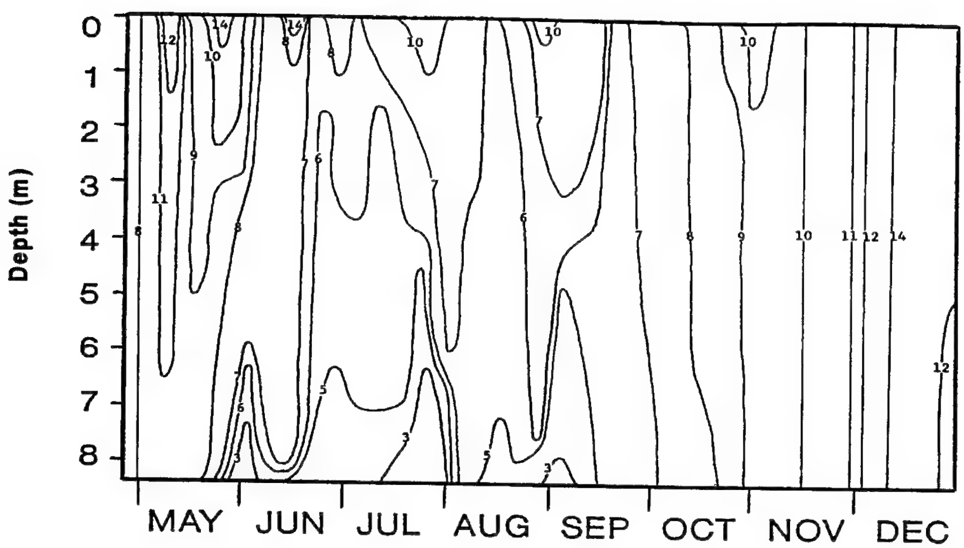

Figure 17. Dissolved oxygen isopleths for middle Lake Pepin site M775.6Q.

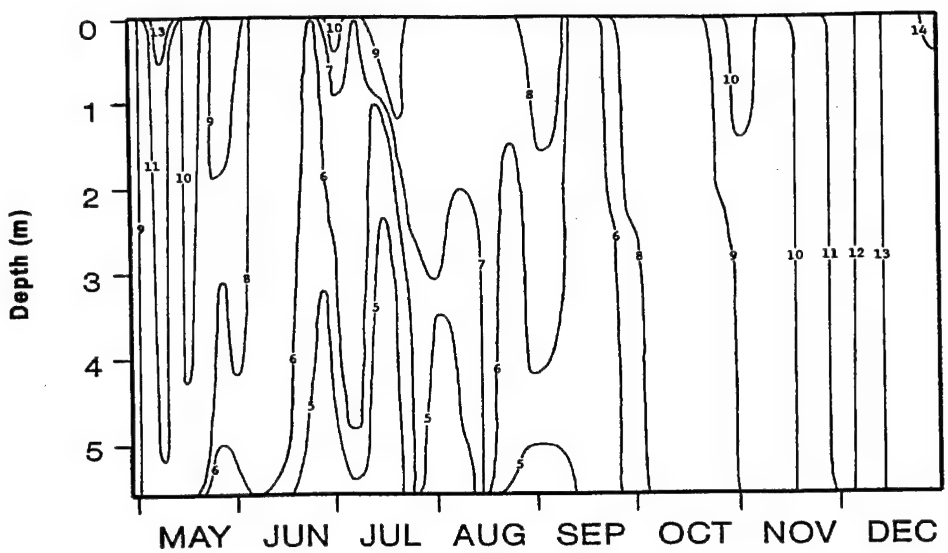

Figure 18. Dissolved oxygen isopleths for lower Lake Pepin site M766.0l.

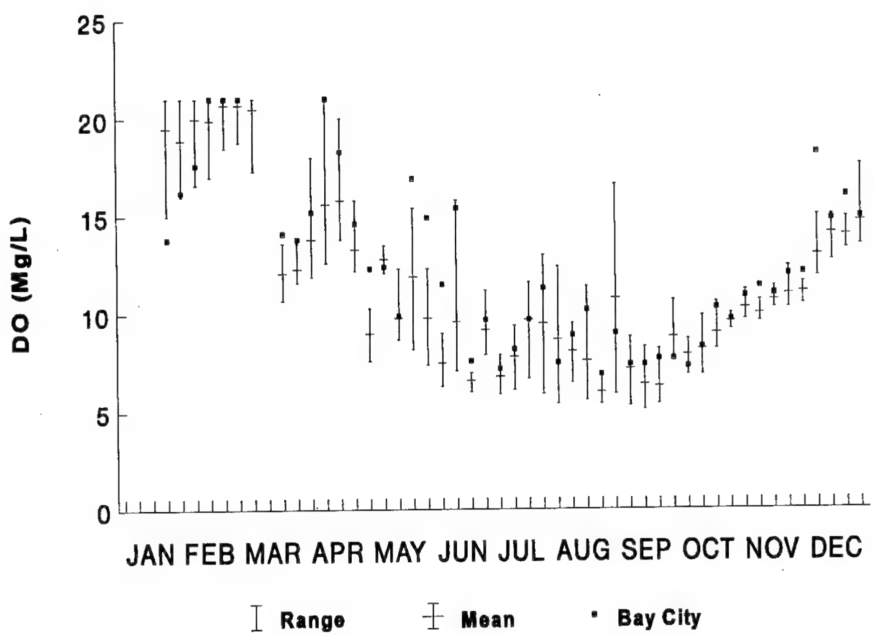

Figure 19. Mean and range of surface dissolved oxygen (DO) in Lake Pepin (Bay City is treated separately).

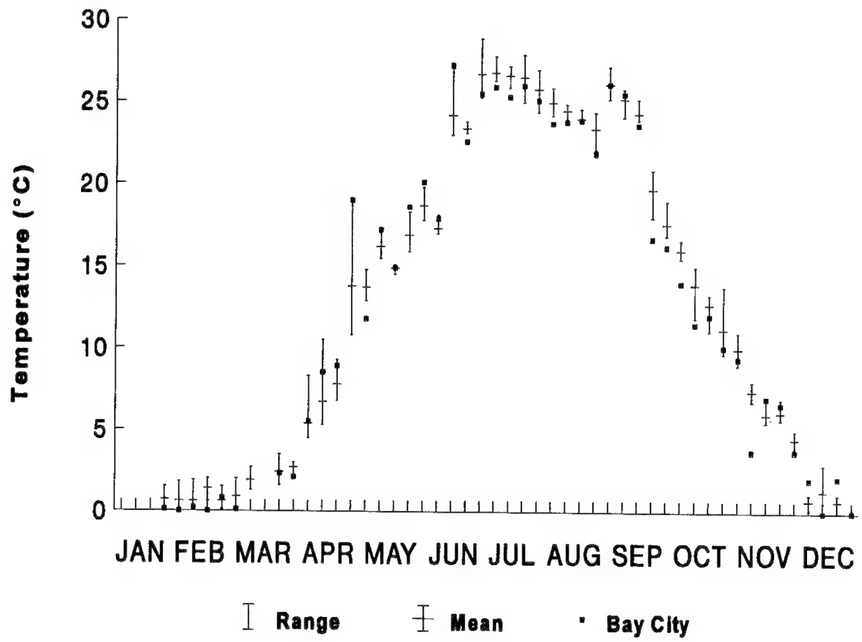

Figure 20. Mean and range of surface water temperature in Lake Pepin (Bay City is treated separately).

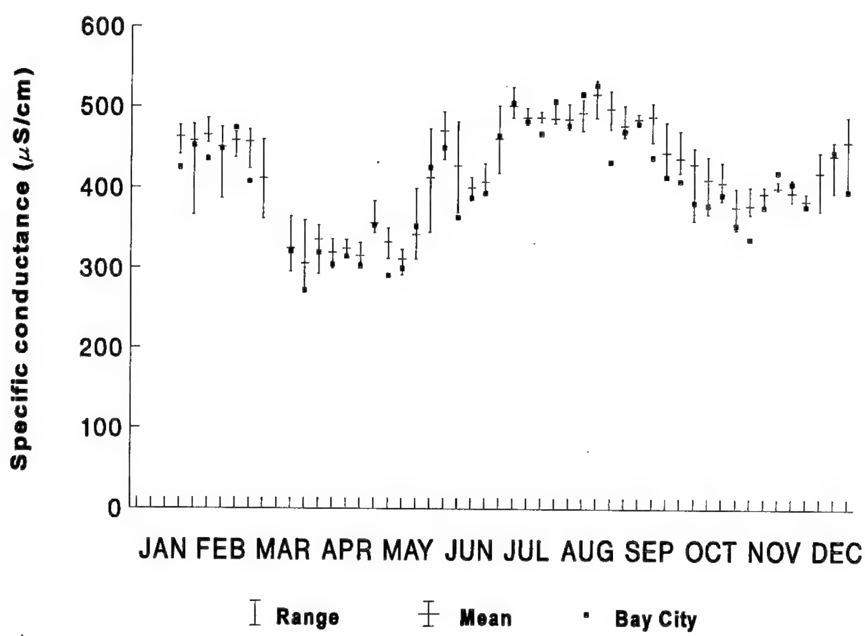

Figure 21. Mean and range of surface specific conductance in Lake Pepin (Bay City is treated separately).

Upper Pool 4

Upper Pool 4 is the section of river running from Lock and Dam 3 to the head of Lake Pepin. The main channel of upper Pool 4 is virtually ice-free in winter because of warmwater discharge from a nuclear power plant just upriver of Lock and Dam 3. The backwaters in this stretch of river contain only scattered, sparse beds of aquatic macrophytes. Because of the lack of vegetation, comparison between vegetated and nonvegetated sites was not possible.

Habitats monitored in upper Pool 4 included unstructured channel border (non-wing dam sites), tailwater, tailwater wing dam, side channel, and contiguous and isolated backwaters (Table). The tailwater and side channel sites were not established until November 1990 and are not included in the analysis.

Dissolved oxygen concentrations and water temperatures were similar among all habitats during most of the year (Figures 22 and 23). In winter, temperatures tended to be slightly higher in the main channel habitats because of the thermal effluent from the nuclear power plant; DO concentrations were slightly lower in the main channel than those in the contiguous backwater. The isolated backwater, which is a small, shallow body of water fed by the Vermillion River during high flows, was very productive, with high densities of phytoplankton and supersaturated DO levels.

Specific conductance was also similar among all habitats of upper Pool 4 (Figure 24). As discussed previously, a decrease in conductivity was observed in spring and fall. The channel border unstructured site tended to have slightly higher conductivity than the tailwater wing dam and backwater sites, which may be attributed to this site's location downstream of the confluence of the Cannon and Vermillion Rivers.

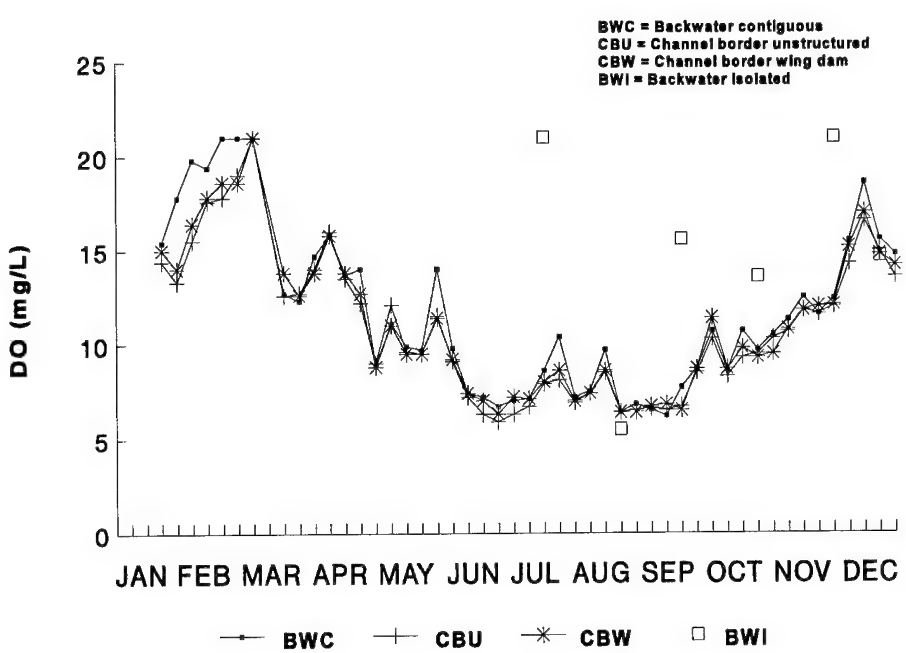

Figure 22. Mean surface dissolved oxygen (DO) for each habitat in upper Pool 4.

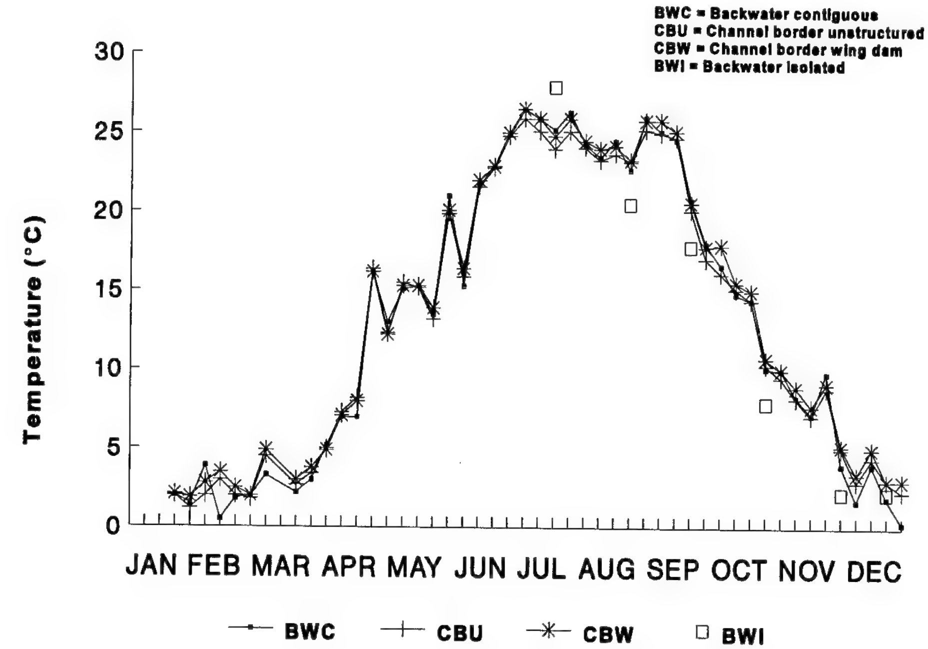

Figure 23. Mean surface water temperature for each habitat in upper Pool 4.

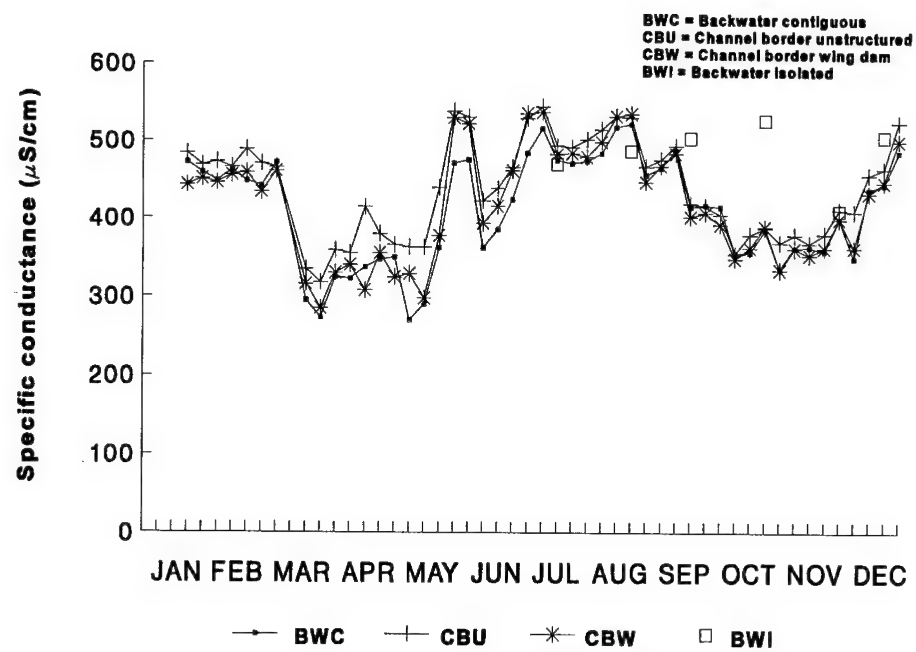

Figure 24. Mean surface specific conductance for each habitat in upper Pool 4.

Turbidity was similar among all habitats except on a few occasions (Figure 25). The peak in turbidity observed in early June at the main channel border and contiguous backwater sites resulted from the load of suspended sediment transported by the Cannon River. Heavy rainfall in the Cannon River watershed in June resulted in high flows and extremely turbid conditions in the Cannon River. The elevated turbidity observed in August through October in the contiguous backwater may be a result of wind and wave action resuspending sediments from the bottom. In winter, turbidity was lower and water clarity greater (Figure 26) for all habitats.

Current velocity in upper Pool 4 (Figure 27) varied with the amount of discharge entering the pool at Lock and Dam 3 and, to a lesser extent, from the Cannon and Vermillion Rivers. The tailwater wing dam site was located just behind a wing dam that is exposed during low flows. During low discharges, an eddy was created and the current ran parallel to the wing dam at relatively slow velocities compared with those of the main channel. During high discharges, water flowed over the wing dam, significantly increasing current velocities. At times, wind may have influenced current velocity in the contiguous backwater, whereas velocity at the main channel border site was dependent primarily on discharge.

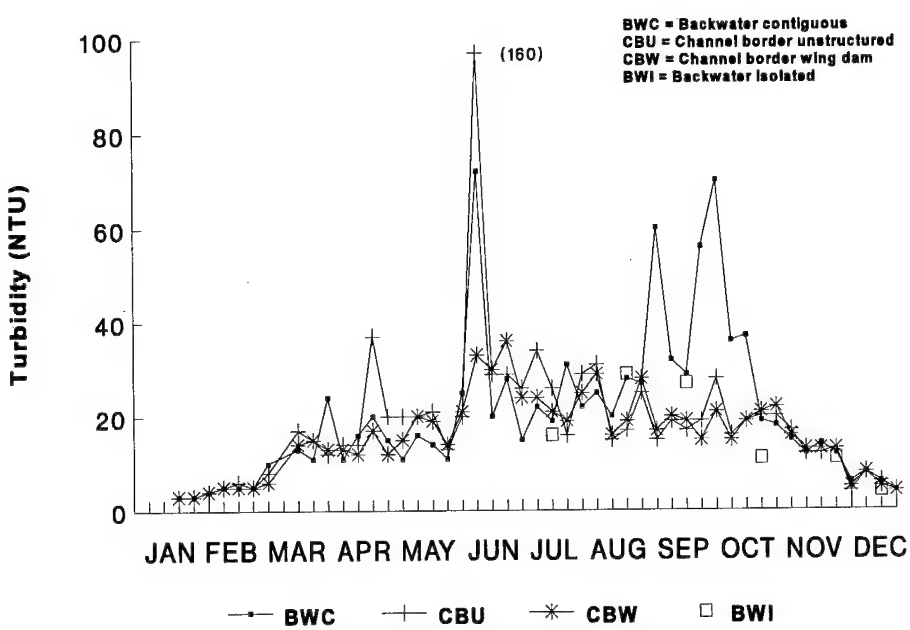

Figure 25. Mean surface nephelometric turbidity for each habitat in upper Pool 4.

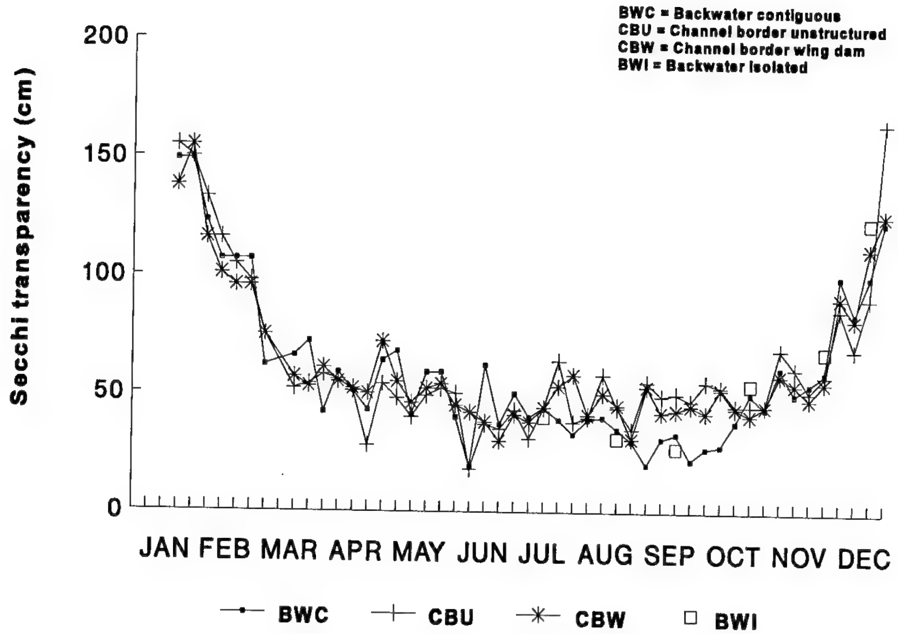

Figure 26. Mean Secchi transparency for each habitat in upper Pool 4.

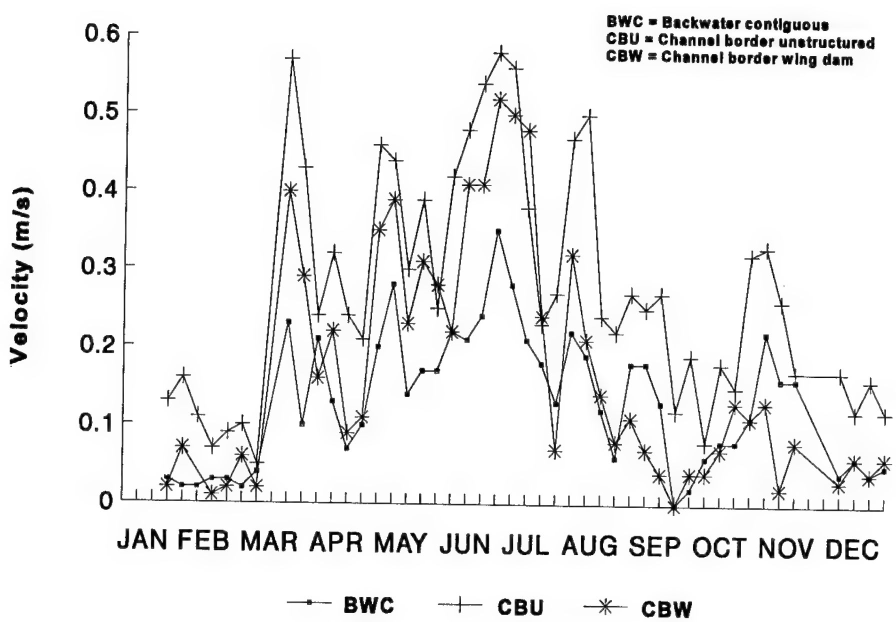

Figure 27. Mean surface current velocity for each habitat in upper Pool 4.

Lower Pool 4

Lower Pool 4 is the section of river running from the lower end of Lake Pepin to Lock and Dam 4. Lower Pool 4 differs considerably from upper Pool 4. Water clarity is greater (Figure 28) and turbidity levels lower (Figure 29) in lower Pool 4 because of the settling of suspended material in Lake Pepin. The backwaters in this stretch of river had abundant aquatic macrophytes as opposed to upper Pool 4, where aquatic vegetation was sparse. Unlike upper Pool 4, the main channel in lower Pool 4 tends to freeze in early winter. As Lake Pepin stratifies, warm water from the hypolimnion and a high current velocity caused by the narrowing of the river at the mouth of Lake Pepin cause the channel to reopen.

Habitats monitored in lower Pool 4 include vegetated and nonvegetated contiguous backwater, vegetated and nonvegetated impounded area, structured and unstructured channel border, and an isolated backwater (Table).

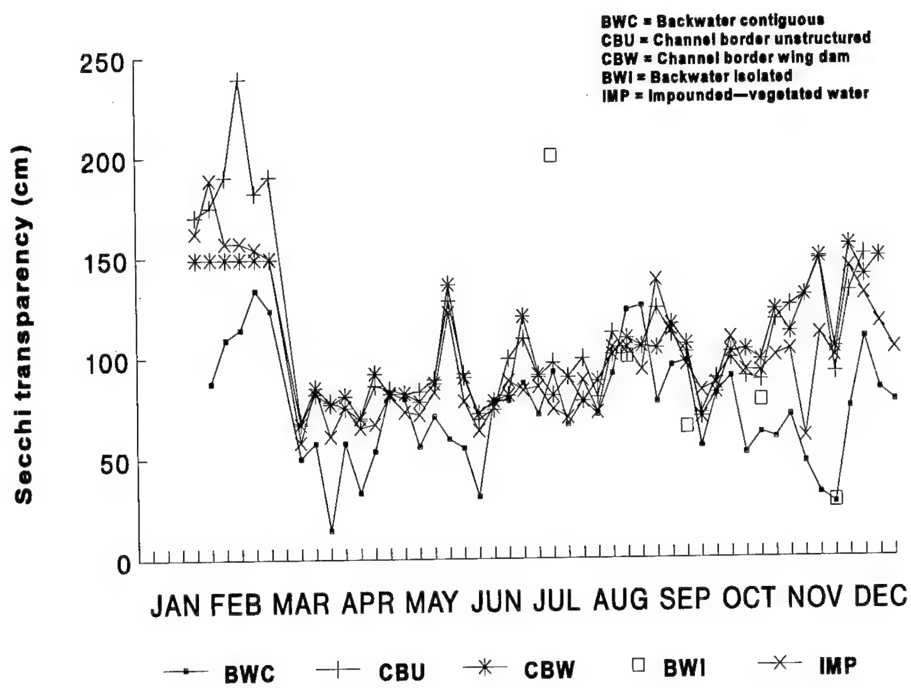

Figure 28. Mean Secchi transparency for each habitat in lower Pool 4.

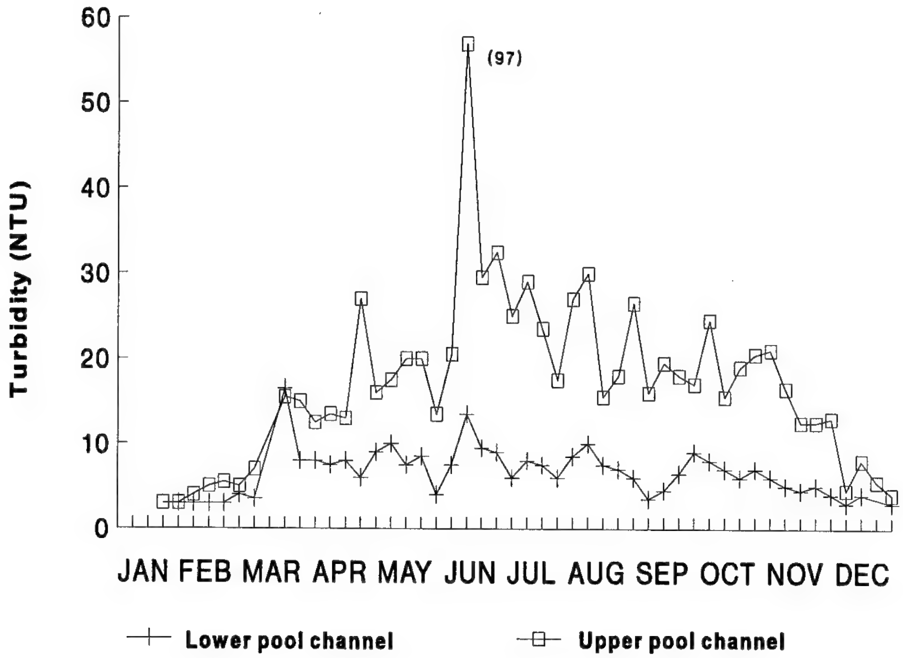

Figure 29. Comparison of surface turbidity at unstructured main channel border sites in upper and lower Pool 4.

Water temperature and DO concentrations were similar among all habitats of lower Pool 4 (Figures 30 and 31) with a few exceptions. Supersaturated DO levels occurred at the vegetated site in the impounded habitat from June through August. The elevated DO levels were caused by a dense bed of macrophytes, consisting primarily of coontail (*Ceratophyllum demersum*) and American wildcelery (*Vallisneria americana*). The vegetated site in the contiguous backwater, consisting primarily of American wildcelery and American lotus (*Nelumbo lutea*), is somewhat of an anomaly in that DO levels in the summer months were often lower than those at the nonvegetated site about 100 m away. Conductivity differences of 100 μS/cm occasionally occurred between the two sites. Unlike the vegetated site in the impounded area (which frequently had saturated and even supersaturated DO levels under the ice), the vegetated backwater site had DO concentrations below saturation in winter. The site may be affected by nearby springs along the shore or a wastewater treatment settling pond approximately 2.4 km (1.5 miles) upstream.

Specific conductance measured at the contiguous and isolated backwater sites was consistently lower than conductance in other habitats of lower Pool 4 (Figure 32). The network of sloughs occurring in the lower reaches of the Chippewa River influenced both backwaters. During high flows in the Chippewa River, these backwaters were inundated with low conductivity water from the Chippewa River. The decrease in conductivity observed in all habitats in August resulted from high flows in the Chippewa River, which affected most of lower Pool 4. The impounded and main channel habitats had similar conductivity to that found in upper Pool 4 and Lake Pepin.

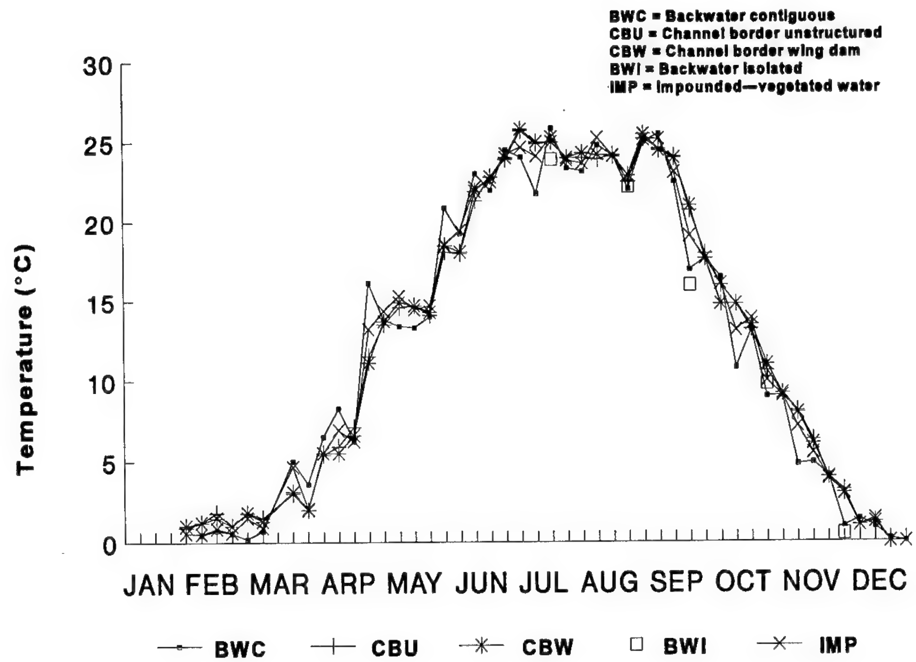

Figure 30. Mean surface water temperature for each habitat in lower Pool 4.

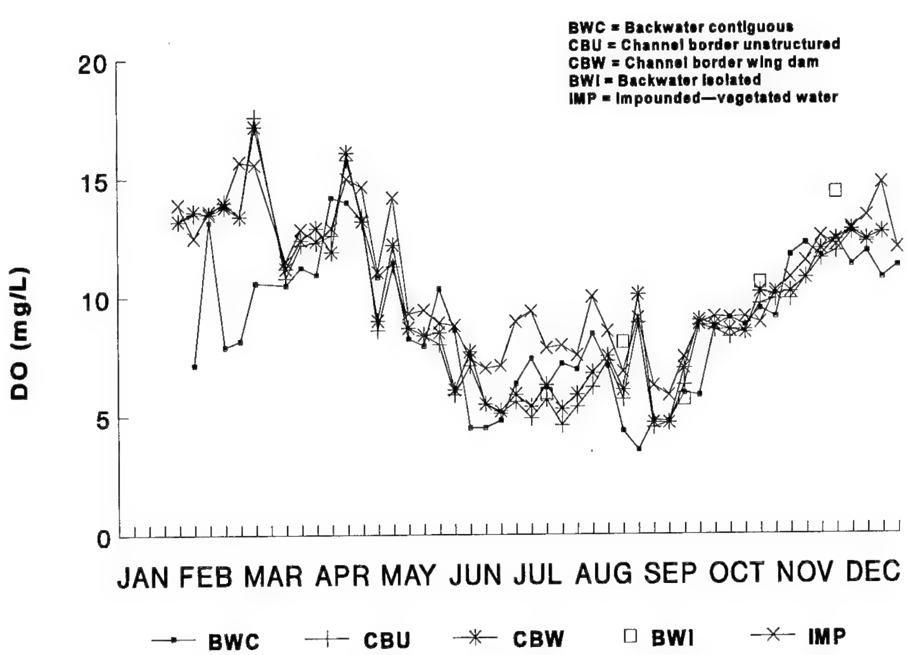

Figure 31. Mean surface dissolved oxygen (DO) for each habitat in lower Pool 4.

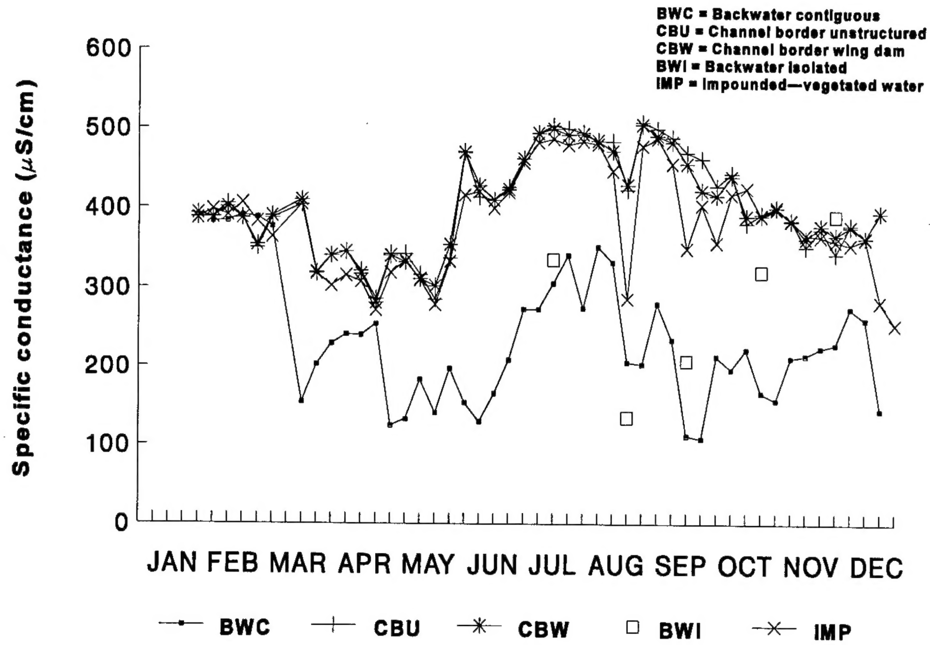

Figure 32. Mean surface specific conductance for each habitat in lower Pool 4.

Turbidity in lower Pool 4 was similar and relatively stable among all habitats except in the contiguous backwater (Figure 33). The contiguous backwater is a large, shallow expanse of water affected by wind and wave action. The peaks in turbidity that occurred in the backwater in spring and fall resulted from high winds that resuspended sediments. High flows in June caused turbidity to increase in all habitats of lower Pool 4. The elevated turbidities were more pronounced in the contiguous backwater because of the unusually high turbidity in the Chippewa River during this period.

Current velocities increased with increased discharge in all habitats (Figure 34). Current velocity in the contiguous backwater and impounded habitats was considerably less than that in the main channel habitats, particularly during high discharge. Current velocity did not differ much between the unstructured and wing dam habitats of the main channel. Unlike the wing dam in upper Pool 4, which is exposed during low flows, the wing dam in lower Pool 4 is always submerged and does not have much effect on current velocity. Current velocities in the main channel of lower Pool 4 tended to be higher than those in the main channel of the upper pool, probably because of the higher discharge in the lower pool caused by the Chippewa River.

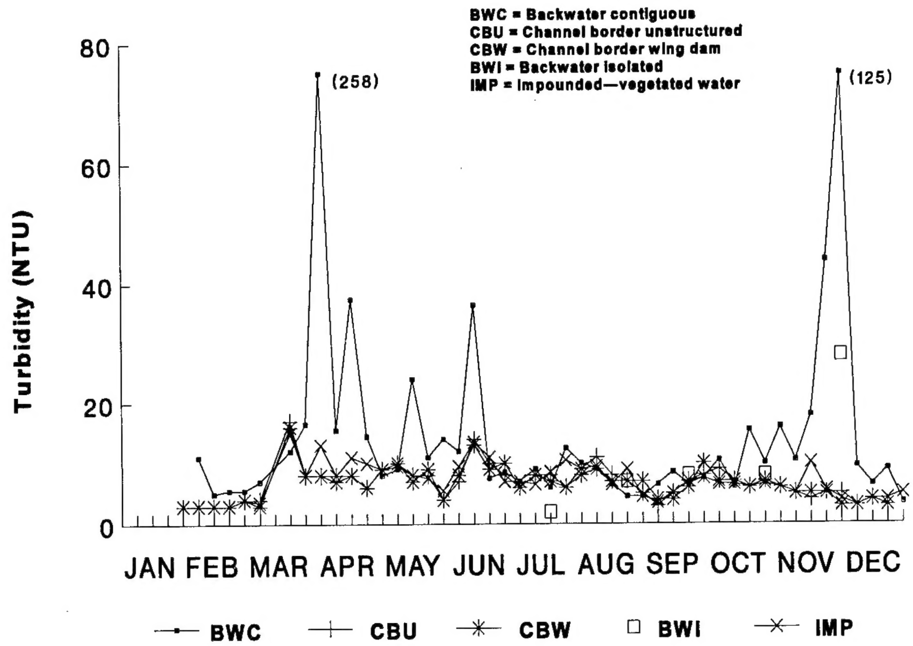

Figure 33. Mean surface nephelometric turbidity for each habitat in lower Pool 4.

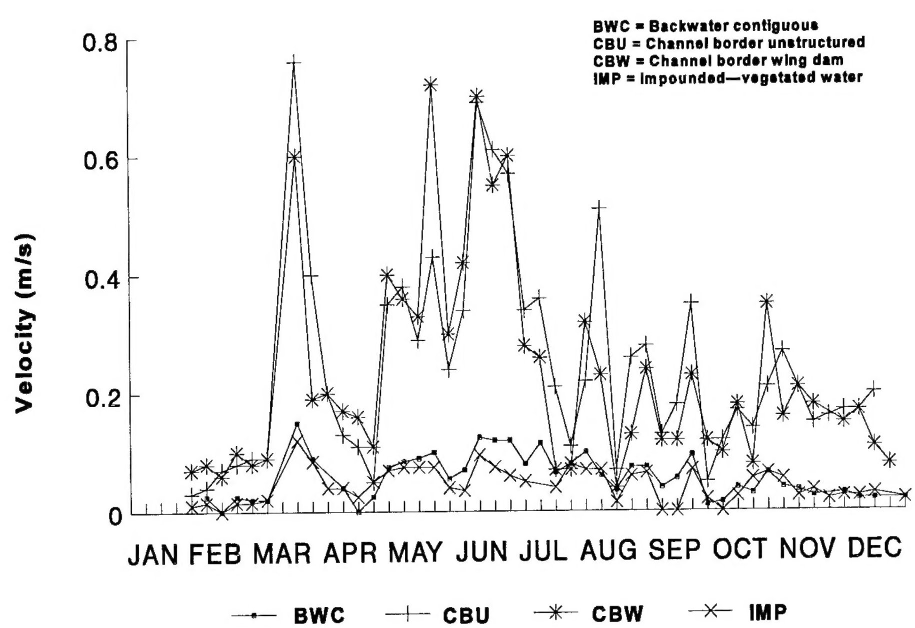

Figure 34. Mean surface current velocity for each habitat in lower Pool 4.

Summary

Perhaps the most salient feature of Pool 4 is Lake Pepin, a eutrophic riverine lake. Lake Pepin acts as a settling basin for suspended material, consequently improving water clarity in the lower pool. In summer, stratification occurred intermittently in Lake Pepin, depending on wind conditions. During summer stratification periods, DO in the hypolimnion decreased to concentrations of 5.0 mg/L and lower. Supersaturated concentrations of DO caused by phytoplankton blooms were frequently measured under the ice and occasionally in the epilimnion in summer.

The backwaters of lower Pool 4 had abundant aquatic macrophytes, whereas the aquatic vegetation in upper Pool 4 backwaters was sparse. Beds of aquatic macrophytes increased dissolved oxygen concentration and slowed current velocity during peak density.

The flow regime of the Chippewa River influences a large area of lower Pool 4 with its highly stained, low-conductivity water. The Cannon and Vermillion Rivers also have distinct water quality characteristics that affect areas of upper Pool 4, but to a much lesser degree than the Chippewa River influences the lower pool.

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Resource Trend Analysis water quality monitoring was initiated in Navigation Pool 4 of the Upper Mississippi River in January 1990 as part of the Long Term Resource Monitoring Program. Water quality sampling was conducted in different habitats of the Upper Mississippi River System to interpret and predict short-term variability and long-term trends.

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